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- nal with its early version on an alternative frequency;
- Fig. 4 shows the correlation result of two probes of the signal transmitter on an alternative frequency with a reference signal generated within the receiver;
- Fig. 5 explains the maximum delay of an alternative frequency in respect to a currently tuned frequency for the checking of the alternative frequency;
- Fig. 6 explains the maximum delay of an alternative frequency in respect to a currently tuned frequency for the checking of the alternative frequency in case the gap part is used as synchronization symbol;
- Fig. 7 explains the maximum delay for a seamless switching from a currently tuned frequency to an alternative frequency;
- Fig. 8 depicts a flow chart for an alternative frequency switching in a receiver adapted to the method and for the radio transmission signal according to the invention; and
- Fig. 9 is a block diagram of a receiver with features according to the invention.

[0015] A digital transmission system embodying the invention should have a frame structure as shown in Fig. 1. The signal in the air generally consists of two parts, i.e.

- a dynamic data-channel (DD) like an audio-channel with interleaving in time, but not repeated, and
- a quasi-static data-channel (SD), e.g. comprising the information about the respective service, i.e. multiplex location, program type, alternative frequency list, transmitter ID and as the case may be additional service information.

[0016] Additionally, a gap can be located within a frame, as also shown in Fig. 1, which could have a variable length depending on the transmission frequency and therefore on the possible delay between the alternative frequencies. For OFDM systems the variable length of the gap might be realized by reducing the total amount of carriers. This gap can either be empty or information transmitted within the quasi-static data-channel can be shifted to the gap.

[0017] The quasi-static data-channel and/or the gap might comprise a guardinterval.

[0018] According to the present invention, the respective dynamic parts of the dynamic data-channel comprise status information for the respective corresponding quasi-static data parts of the quasi-static data-channel or the quasi-static data-channel and the gap. This status information might show the frame number of the following frame in which the quasi-static data part and if applicable the gap part comprise the identical symbols as the quasi-static data part and if applicable the gap

part of the frame comprising the status information. In an advantageous embodiment the dynamic data-channel carries also a frame counter in every dynamic data part indicating the respective frame number.

[0019] For the following description the assumption is made that a frame consists of a gap part GAP, a quasi-static data part SD comprising one symbol and a dynamic data part DD as shown in Fig. 1. Of course, the order of SD and GAP can be changed. Furtheron, the status information should be valid for the symbols included within the static data part and within the gap part. Both, the gap part and the quasi-static data part comprise a guardinterval.

[0020] The quasi-static data part should preferably satisfy the following rules:

- The quasi-static data should be in general identical and unique for all services, reference carriers are allowed,
- data included in the gap should be in general identical and unique for all services,
- the quasi-static data provides a frequency synchronization possibility that must not necessarily be a phase reference symbol like transmitted in DAB,
- the frame counter and status information have to be outside the static data part and gap part.

[0021] As mentioned above, the repetitive part of the signal is the GAP and SD. On all frequencies of the same service the GAP and the SD are in general the same and unique for this service, i.e. no other service has the same GAP and SD. This might be supported by a specific scrambling of data.

[0022] During the time the repetitive part at the current frequency occurs, i.e. the status information for GAP and SD of an earlier frame indicated that the GAP and SD of the current frame has already been transmitted at least once, the receiver can check an alternative frequency. In the present case at least one set of samples, e.g. one spot of several samples, is taken from the alternative frequency as a signal probe and will be correlated with a reference signal within the receiver to gather some information about the alternative frequency. This reference signal might be simply a copy of a previously received GAP and SD in the time domain or can also be a rebuilt signal that is gathered from the information of one or more previously received GAPs and SDs.

[0023] On basis of the correlation peak(s) the receiver can decide if the alternative frequency comprises the same service and in addition the time synchronization can be calculated. If two spots of several samples are correlated, additionally a frequency synchronization, i.e. an estimation of  $\Delta f$  in-between the current frequency or nominal frequency and the alternative frequency can also be calculated.

[0024] At the next repetitive part the receiver is then able to switch to the alternative frequency before the SD-symbol occurs on the alternative frequency to use

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the - known - SD symbol as a phase reference for coherent demodulation, because all carriers are known when switching to the alternative frequency.

[0025] In connection with Fig. 2 the checking of an alternative frequency and the switching thereto is described with a delayed alternative frequency. During the GAP and SD of a frame transmitted on the current frequency three sets of samples of the signal transmitted on the alternative frequency are taken as signal probe. Since two of those sets are taken from the signal carrying the GAP and SD of the corresponding frame transmitted on the alternative frequency the receiver can validly detect if the signal transmitted on the alternative frequency is the same as the currently received signal, and can validly perform a time and frequency synchronization to the alternative frequency. If it is decided within the receiver that the alternative frequency has a better signal quality than the current frequency the receiver is switched to the alternative frequency in the following frame, like it is shown in Fig. 2, before the static data part of the following frame is transmitted on the alternative frequency. Therefore, the known symbol transmitted as static data part on the alternative frequency can serve as a phase reference for the coherent demodulation of the AF-signal, i. e. the signal received on the alternative frequency. Such a fast seamless switching can be performed, since the receiver already has the information for time and frequency synchronization to the alternative frequency and only needs a phase reference.

[0026] Fig. 3 shows the same scenario in case the alternative frequency transmits a frame earlier than the corresponding frame on the current frequency. Also in this case the switching to the alternative frequency is performed before the SD-symbol occurs on the alternative frequency.

[0027] Fig. 4 shows the respective correlation of two sets of samples with the reference signal stored within the receiver. It can clearly be seen that one correlation peak occurs in each of the correlation signals.

[0028] In case the AF-signal is the same as the reference signal which is based on the currently received signal, a correlation peak occurs. Since the correlation peak occurs only if the AF-signal is the same as the currently received signal it can be used for the decision if the AF-signal is the same as the currently received signal or not. In the shown case one correlation peak is included within each of the correlation signals, therefore the signals of both sets of samples are included within the reference signal.

[0029] To provide a seamless switching from the current frequency to the alternative frequency, a fast synchronization of the receiver to the AF is required. Therefore, information for time and frequency synchronization that was gathered before the switching can now be used as explained above.

[0030] The information for the time synchronization is received by an evaluation of the position of the correlation peak or peaks. The position of a correlation peak

shows exactly the time difference  $\Delta t$  between the currently received signal and the AF-signal as it is shown in Fig. 2. Therefore, the receiver is able to perform a quick time synchronization on basis of this time difference.

[0031] For calculating the information for the frequency synchronization at least two correlation peaks are required. Additional correlation peaks are determined in time by the first correlation peak and the probe offset. The frequency synchronization information is then gathered by an evaluation of the phase difference between the two correlation peaks. Under the assumption of an ideal channel a phase difference between both correlation peaks can only be caused by a time or frequency error. Due to the high accuracy of the sampling clock of the transmitter and receiver the time error is neglectable. Therefore, the phase difference results basically from a frequency offset. The frequency offset  $\Delta f$  between the currently received signal and the AF-signal can then be calculated from the following equation:

$$\varphi_{\text{peak1}} - \varphi_{\text{peak2}} = \omega_{\text{offset}} \cdot t = 2 \cdot \pi \cdot \Delta f \cdot t_{\text{peak1-peak2}}$$

$$\Delta f = (\varphi_{\text{peak1}} - \varphi_{\text{peak2}}) / (2 \cdot \pi \cdot t_{\text{peak1-peak2}})$$

wherein  $\varphi_{\text{peak1}}$  and  $\varphi_{\text{peak2}}$  are the phases of the two correlation peaks, and  $t_{\text{peak1-peak2}}$  is the time difference between both correlation peaks.

[0032] The maximum frequency offset that can be detected is depending on the time difference  $t_{\text{peak1-peak2}}$  and is calculated to:

$$\Delta f_{\text{max}} = \pm 0,5 \cdot (t_{\text{peak1-peak2}})^{-1}$$

[0033] The smaller the time difference  $t_{\text{peak1-peak2}}$  the higher the range of the detectable frequency offset, but the longer the time difference  $t_{\text{peak1-peak2}}$  the more exact the frequency estimation. Therefore, preferably three signal probes of the AF-signal are used for the frequency synchronization.

[0034] The correlation of the reference signal and the at least one set of samples of the AF-signal is performed in the time domain. As mentioned above, the reference signal can either be the time domain signal of the GAP and SD of an earlier frame carrying the same symbols as the frame within the testing is performed or can be re-calculated in the receiver on basis of the information of one or more previous GAPs and SDs.

[0035] With the help of Fig. 5 in the following the maximum delay of an alternative frequency to the current frequency or of the current frequency to an alternative frequency for the AF-check is illustrated. Fig. 5 shows that the length of the GAP including the guardinterval is  $T_{\text{GAP}}$ , the length of the static data part including the guardinterval is  $T_{\text{S}}$  and the time in which one set of sam-

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ples is transmitted is  $T_{corr}$ . In the shown example the gap length is constant for all frequencies. Since the checking of an alternative frequency 1 which is delayed in respect to the current frequency and of an alternative frequency 2 which is earlier than the current frequency has to be performed within the GAP and SD transmitted within the frame of the current frequency and the GAP and SD of the same frame transmitted on the respective alternative frequency the maximum delay  $T_{Dcheck,max}$  of an AF to the current frequency or of the current frequency to an AF is defined by the following formula:

$$T_{Dcheck,max} = \pm (T_S + T_{GAP} - 2 \cdot T_{corr} - 2 \cdot T_{PLL})$$

where  $T_{PLL}$  is the switching time of the PLL from one frequency to another.

[0036] For an easier synchronization the GAP could be a sync-symbol which is equal on all transmissions (all broadcasters and services have the same GAP). Therefore, at least one set of samples has to be from the static data part to validate the same service. As shown in Fig. 6 which directly corresponds to Fig. 5, this causes a shorter maximum delay for the AF-check, i. e.:

$$T_{Dcheck,max} = (T_{GAP} - T_{PLL} - T_{corr})$$

[0037] Seamless AF-switching is only possible if a phase reference for the coherent demodulation is available. Preferably the SD can be used as phase reference, because all carriers are known when switching to the alternative frequency. In this case the maximum delay for the switching is shorter than the maximum delay for checking. Fig. 7 directly corresponds to Figs. 5 and 6 and shows that the switching from the current frequency to an alternative frequency should be performed at least during the guardinterval of the static data part transmitted on the alternative frequency. The maximum delay  $T_{Dswitch,max}$  for AF-switching is calculated according to the following formula:

$$T_{Dswitch,max} = T_{GAP} - T_{PLL} + T_S$$

where  $\Delta T_S$  is the length of the guard interval of the static data part.

[0038] Fig. 8 that consists of Fig. 8a and Fig. 8b which fit together at connection points ① and ② shows a flow chart describing the AF-switching procedure. The receiver is currently tuned to a frequency F1 and has already got the information about the alternative frequency F2, e. g. received in the previous SD and GAP. The flow chart depicts two alternative methods A and B to generate the reference signal SREF

$$S_{REF} = \text{time-mux} \{ \Delta_{GAP}, GAP, \Delta_{SD}, SD \}$$

wherein  $\Delta_{GAP}$  is the guardinterval of the gap,  $\Delta_{SD}$  is the guardinterval of the static data part and time-mux indicates that the following signal parts are transmitted in time-multiplex.

5 [0039] In a first step S1 the signal transmitted on the frequency F1 is received and the information about an alternative frequency F2, e. g. gathered from a previous SD and GAP, is stored. Thereafter, in a step S2 it is decided whether method A or method B is performed to generate the reference signal SREF.

10 [0040] In case method A is performed step S3 is carried out in which the received  $\{ \Delta_{GAP}, GAP, \Delta_{SD}, SD \}$  is stored as reference signal SREF in the time domain as real or complex signal. Thereafter, it is checked in step 15 S4 whether the next transmitted SD and GAP is the same as before on basis of the reference signal SREF.

[0041] The decision whether the next SD and GAP is checked in step S4 depends on the indicator included in the dynamic data part, since this indicator indicates 20 which of the following frames transmits the same SD and GAP as the frame which served as a basis for generation of the reference signal SREF.

[0042] If the next GAP and SD is not the same as the one on basis of which the reference signal SREF is generated step S2 is again performed. If, on the other hand, it is decided that the next GAP and SD corresponds to the GAP and SD on basis of which the reference signal SREF is generated the receiver waits in step S5 for the next GAP, since this is transmitted before the SD in this embodiment of the present invention. Thereafter, when 30 the beginning of the next GAP is received, the phase locked loop (PLL) of the receiver is set to the frequency F2 in step S6 and a signal probe and the reception quality is gained out of the new signal F2 in step S7 before the phase locked loop is again set to the frequency F1 in step S8.

[0043] During the following reception of the signal transmitted on the frequency F1 the receiver performs a correlation of the sets of samples, i. e. the probe, with the reference signal SREF in step S9 to decide whether the reference signal and the probe belong to the same service or not in step S10. If this is not the case step S2 is again performed, otherwise, i. e. if the reference signal and the probe belong to the same service, the information for time and frequency synchronization to the new frequency F2, namely the time and the frequency deviations  $\Delta t$  and  $\Delta f$  is calculated in step S11 and stored in step S12. In step S13 it is decided whether the frequency F2 has a better signal quality than the frequency F1. 40 If this is not the case step S2 is again performed. If this is the case the best switching point is calculated in step S14 before the phase locked loop of the receiver is set to the frequency F2 at this best switching point in step S15 and the quasi-static data part SD transmitted on the frequency F2 is used as phase reference for the coherent demodulation in step S16.

[0044] If it is decided in step S2 that the method B should be performed instead of method A steps S17 to

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S23 are carried out instead of steps S3 to S8.

[0045] Therefore, in step S17 the decoded GAP and SD is stored before it is decided in step S18 whether the next GAP and SD corresponds to the stored ones in step S18. This step S18 directly corresponds to step S4 and therefore depending on the indicator within the dynamic data part also another corresponding GAP and SD could be checked. If no corresponding GAP and SD exists again step S2 is performed (the same situation as in connection with step S4). If, on the other hand, the GAP and SD which has been stored in step S17 will be retransmitted again then  $\{A_{GAP}, GAP, A_{SD}, SD\}$  will be rebuild in the time domain and stored as reference signal  $S_{REF}$  in step S19. Thereafter, the receiver waits for the next GAP in step S20 (corresponding to step S5), sets then the PLL to the frequency F2 in step S21 (corresponding to step S6), gets several sets of samples and the reception quality out of the new signal received on the frequency F2 in step S22 (corresponding to step S7) and sets the PLL to the frequency F1 in step S23 (corresponding to step S8) before again proceeding with step S9.

[0046] The typical hardware structure of a digital receiver adapted to perform the method according to the invention is shown in Fig. 9. The transmission signal, in particular a Digital Radio Mondial signal, is received by an antenna 1 and after amplification passes a selective pre-stage 2 and is supplied to a first input of a mixer 3 that receives as a second input thereof a frequency control signal supplied by a control unit 4. Following an IF filter stage 5, the resulting signal is supplied to one input of a mixer 6 supplied at its other input thereof a frequency control signal from the control unit 4. The resulting signal is again filtered in IF filter 7 before its level is adjusted in an automatic gain control (AGC) circuit 8 and AD/conversion in an A/D-converter 9. The automatic gain control circuit 8 also receives a control signal from the control unit 4. The digital signal supplied from the A/D-converter 9 undergoes an IQ-generation in an IQ-generator 10 before a FFT is performed in an equalizer 11 and the resulting signal is demodulated by a demodulator 12 and the channels get decoded by a channel decoder 13. The decoded channels are then input to an audio decoder 14 which outputs a digital audio signal that gets converted by a D/A-converter 15 and to a data decoder 16 which outputs digital data. The control unit 4 further receives the amplitude corrected and digitized output signal of the A/D-converter 9 either direct or as IQ-signals from the IQ-generator 10. To be able to rebuild the reference signal  $S_{REF}$  the output signal from the channel decoder 13 is also fed through a channel coder 17, a modulator 18 and an IFFT circuit 19 which performs an Inverse Fast Fourier Transformation before being input to the control unit 4.

[0047] If a buffer for the received signal is additionally provided within the receiver a switching without losing any information, i. e. a seamless switching, is possible in any situation and not restricted to the maximum delay

times calculated above

[0048] If the quasi-static data has a higher volume than to be transmitted within one frame the GAPs and SDs of several frames can be used for the transmission.

In this case the indicator within the dynamic data part indicates the transmission cycles of the same data or the next frame in which the same data is again transmitted. This could be done in relation to the frame counter. Also, in this case the receiver has to store all possible GAPs and/or SDs.

[0049] The gap length can preferably be variable by decreasing or increasing the carriers in the gap. As preferably the AF-list will be transmitted in the gap which includes the frequency, the transmitter ID and geographical data, this information can be used for hyperbolic navigation if at least three alternative frequencies can be received in a present receiver position.

[0050] Since the gap and/or quasi-static data should be in general identical and unique for all services the data included therein can be scrambled in order to get uniqueness, if necessary.

#### Claims

1. Radio transmission signal consisting of signal frames that comprise a dynamic data part (DD) and a quasi-static data part (SD), **characterized in that** the dynamic data part (DD) of a respective frame contains an indicator (Status) showing in which following frame the quasi-static data part (SD) of this respective frame will be repeated.
2. Radio transmission signal according to claim 1, **characterized by** a gap part (GAP) in each frame which length might depend on the transmission frequency or the possible delay ( $\Delta t$ ) between the receivable alternative frequencies and which can also comprise quasi-static data which will be repeated according to said indicator (Status).
3. Radio transmission signal according to claim 1 or 2, **characterized by** reference carriers within the static data part (SD).
4. Radio transmission signal according to claim 1, 2 or 3, **characterized by** a respective guard interval before at least one of the parts of the radio transmission signal.
5. Radio transmission signal according to anyone of claims 1 to 4, **characterized by** a frame counter within the dynamic data part.
6. Radio transmission signal according to anyone of claims 1 to 5, **characterized in that** it is a digital short-, medium- or longwave signal.

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7. Method to perform a seamless switching of a receiver for radio transmission signals according to any one of claims 1 to 6 from a first currently tuned frequency to a second alternative frequency, **characterized by the following step:**  
receiving at least one set of samples from a respective signal transmitted on at least one second frequency during a time period during which said indicator assures that it is secure that only data that has been transmitted at least once is transmitted as signal on said first frequency.
8. Method according to claim 7, **characterized by the following step:**  
performing a correlation of a reference signal stored within the receiver with one of said at least one set of samples from the respective signal transmitted on said at least one second frequency to check whether the signal transmitted on the respective both frequencies is the same signal on basis of the correlation signal.
9. Method according to claim 8, **characterized in that** a respective time difference ( $\Delta t$ ) between the signal transmitted on the first and respective second frequencies is calculated on basis of the correlation signal.
10. Method according to anyone of claims 7 to 9, **characterized by the following step:**  
performing a respective correlation of a reference signal stored within the receiver with each of at least two sets of said at least one set of samples from the respective signal transmitted on said at least one second frequency to calculate the frequency offset ( $\Delta f$ ) of the respective second frequency in respect to the first frequency on basis of the correlation signals.
11. Method according to anyone of claims 8 to 10, **characterized in that** said reference signal is a copy of the signal received on the first frequency for which the indicator shows in which following frame it will be repeated.
12. Method according to anyone of claims 8 to 10, **characterized in that** said reference signal is a signal which is rebuild in the time domain on basis of the information carried by the signal received on the first frequency for which the indicator shows in which following frame it will be repeated.
13. Method according to anyone of claims 7 to 12, **characterized by the following step:**  
switch to one of said at least one second frequency at a point of time at which it is secure that only data that has been transmitted once will be received on the second frequency so that a symbol of

the newly received signal comprising data already known to the receiver can be used as phase reference for the demodulation of the signal transmitted on the second frequency.

14. Method according to anyone of claims 7 to 13, **characterized in that** a switching to one of said at least one second frequency is performed in case said one of said at least one second frequency has the best reception quality of the signals received on the first and respective second frequencies.
15. Receiver that is adapted to switch from a first currently tuned frequency to a second alternative frequency, **characterized by**
  - a memory to store a part of the received signal of the first frequency or a signal rebuild on basis of the information of a part of the received signal of the first frequency with a rebuild section as reference signal, and
  - a correlator to perform a correlation of the reference signal with at least one probe of a signal received on said second frequency to
    - decide whether the same service is transmitted on both frequencies, and/or
    - calculate the time offset ( $\Delta t$ ) in-between the signals transmitted on both frequencies, and/or
    - calculate the frequency offset ( $\Delta f$ ) in-between both frequencies.
16. Receiver according to claim 15, **characterized in that** said rebuild section comprises:
  - a channel coder (17) receiving the information of a received signal;
  - a modulator (18) receiving the output signal of the channel coder (17); and
  - an IFFT circuit (19) receiving the output signal of the modulator (18) to rebuild the transmission signal of the modulated information of the received signal.
17. Receiver according to claim 15 or 16, **characterized in that** said memory is located within a control unit (4).
18. Receiver according to anyone of claims 15 to 18, **characterized in that** it is adapted to perform the method defined in anyone of claims 7 to 14.
19. Receiver according to anyone of claims 15 to 19, **characterized in that** it is adapted for analog or digital short-, medium- and/or longwave signals, DAB, DVB-T, ADR and/or FM signals.

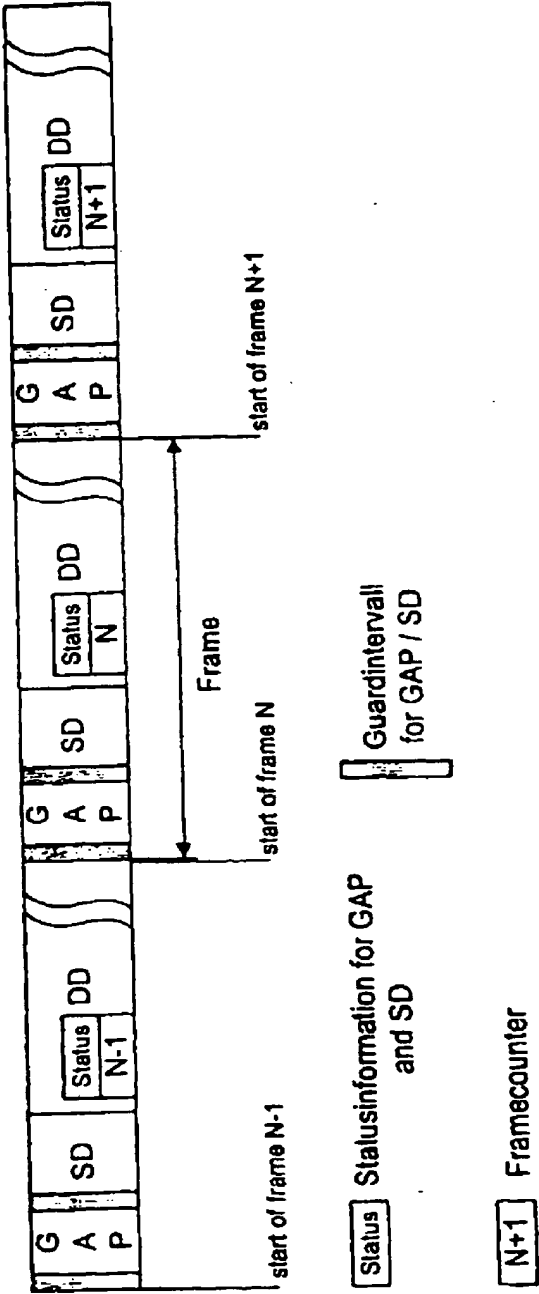


Fig. 1

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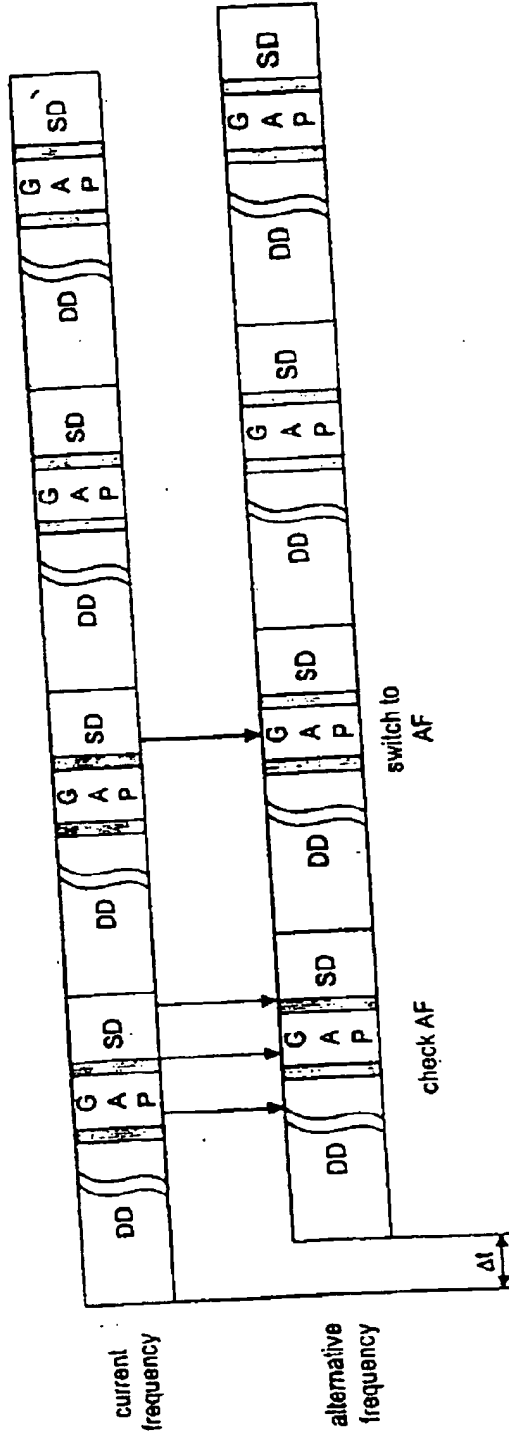


Fig. 2

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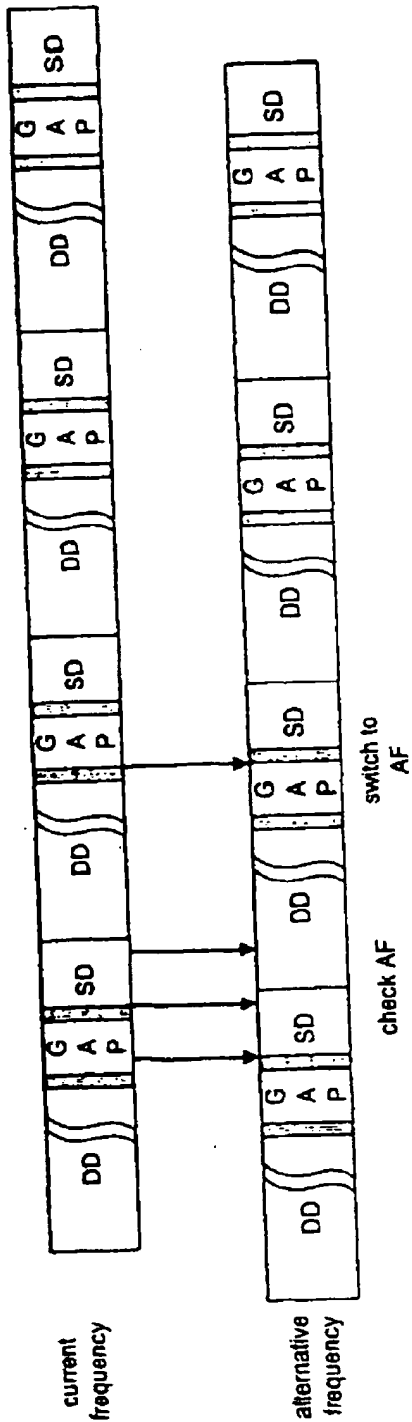


Fig. 3

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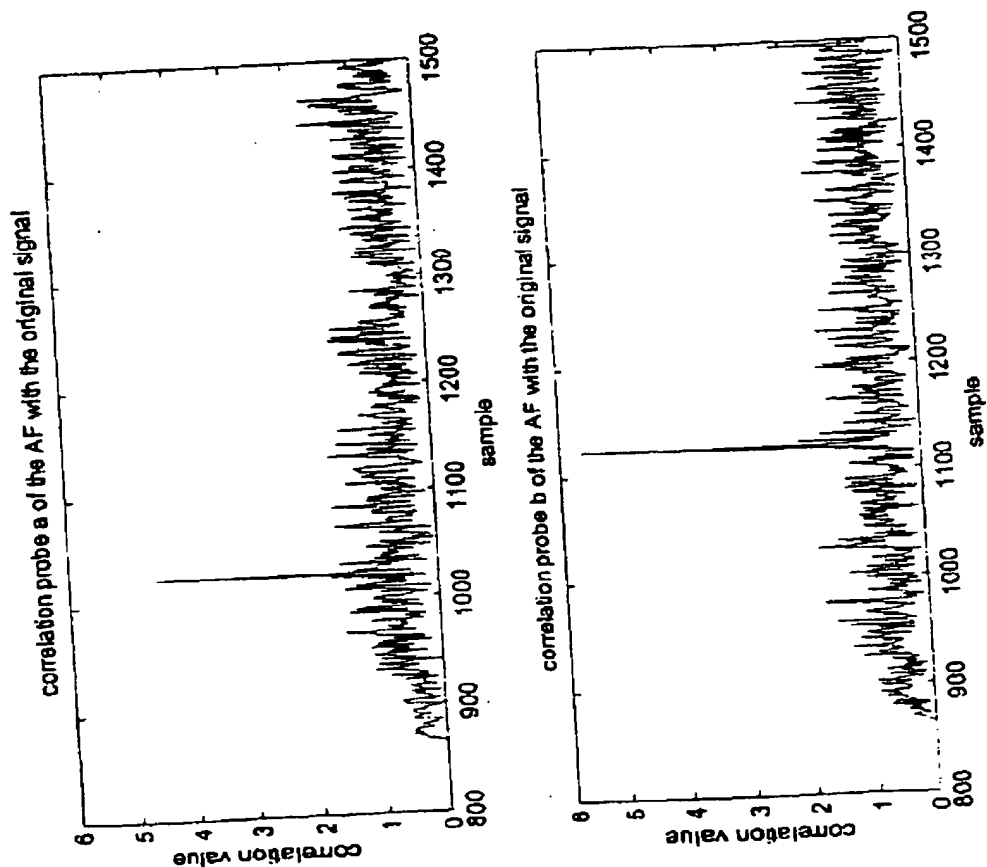


Fig. 4

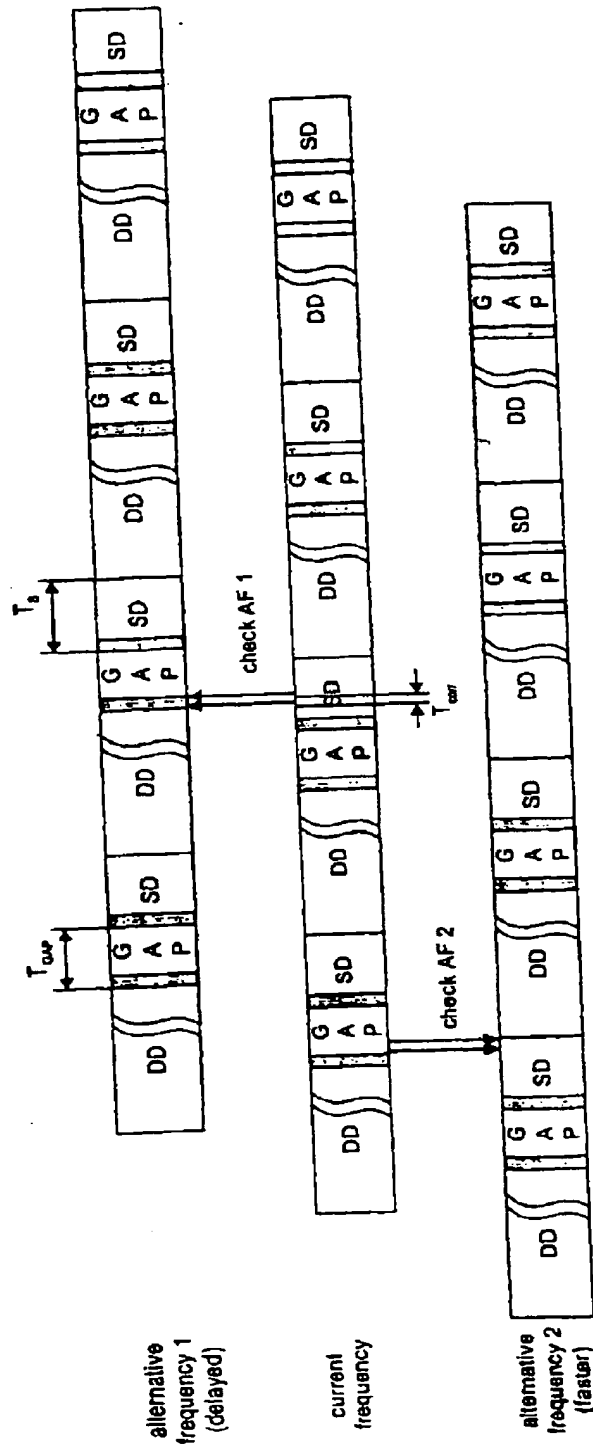


Fig. 5

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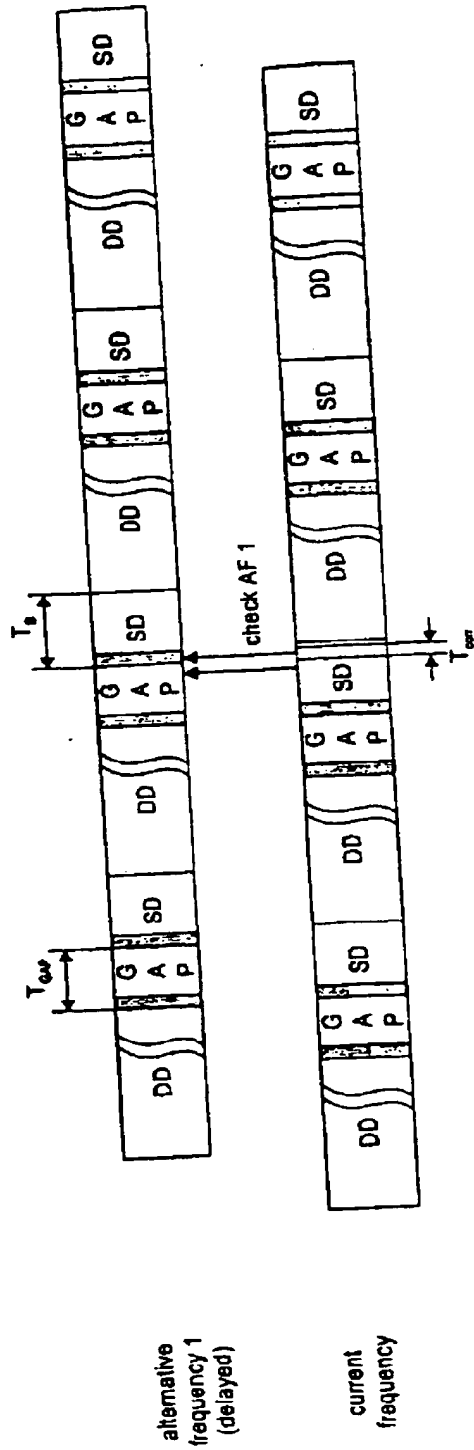


Fig. 6

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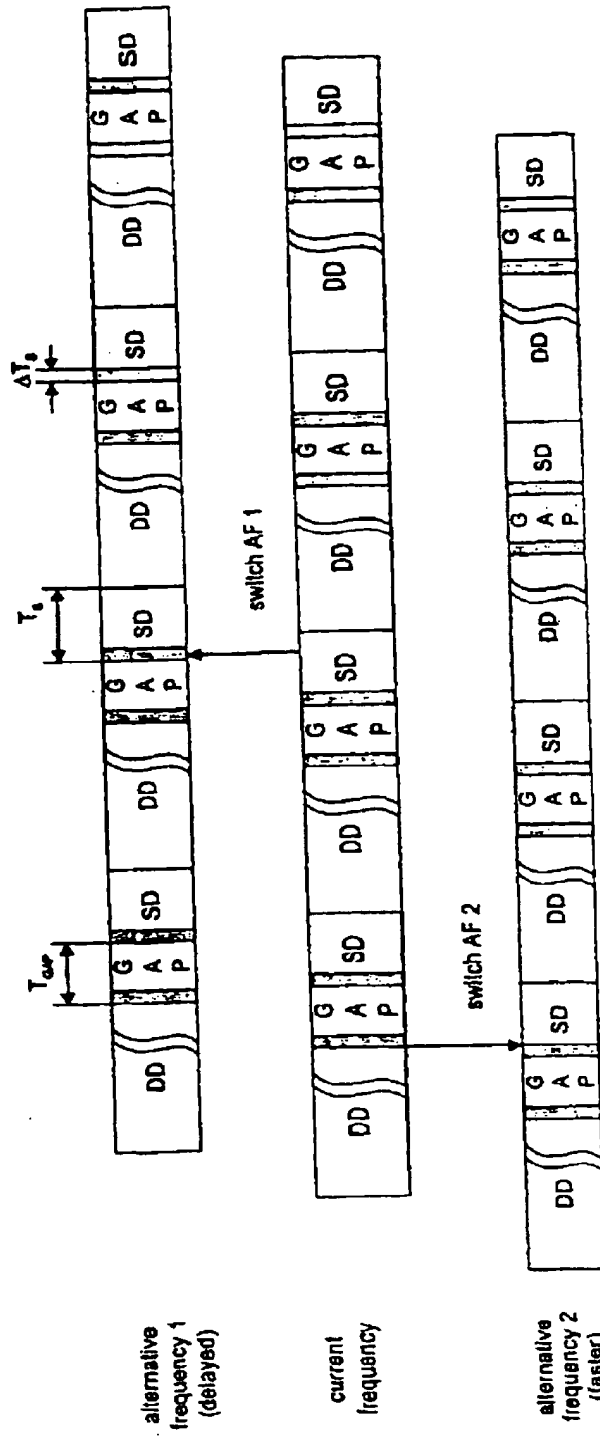


Fig. 7

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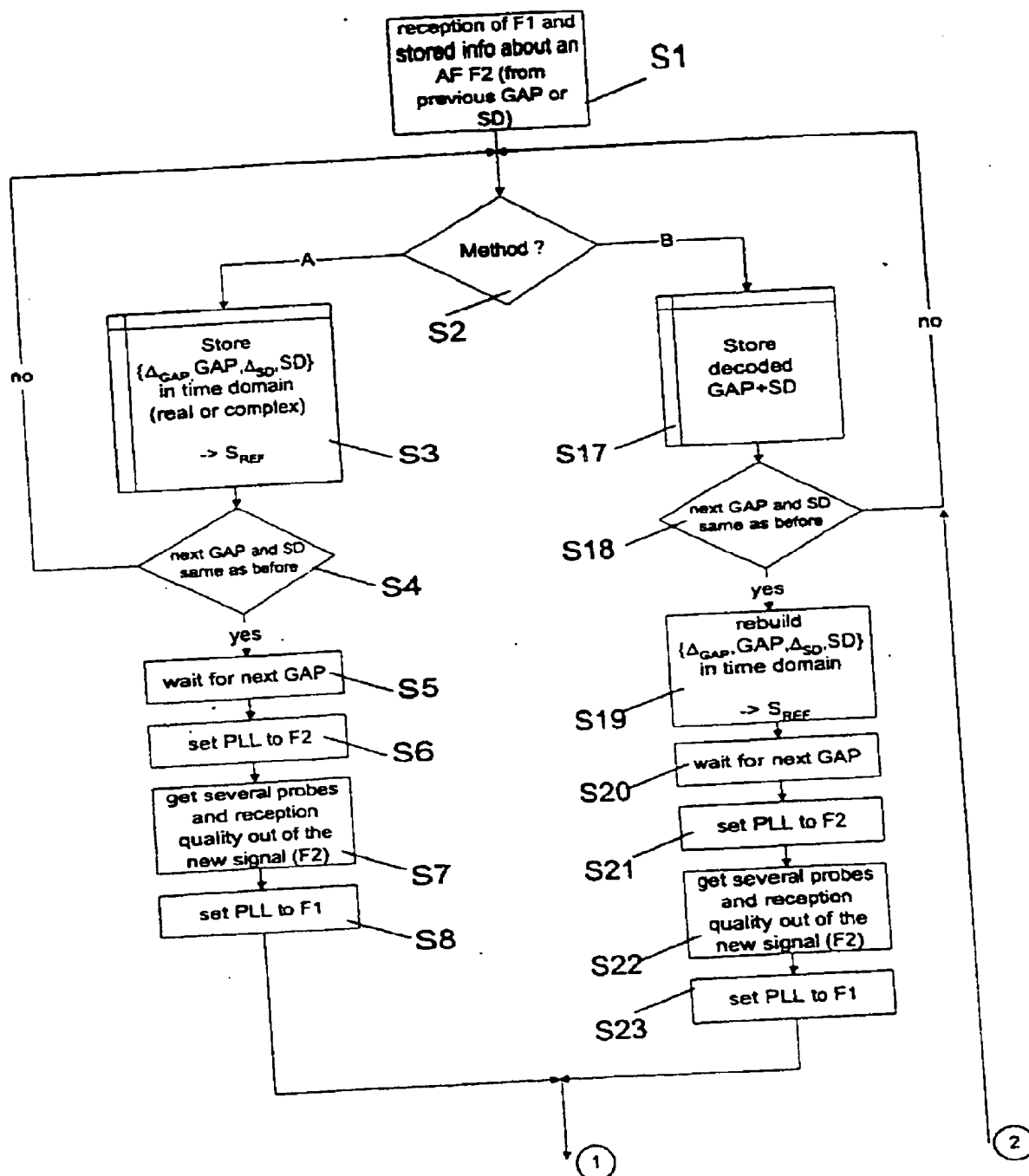


Fig. 8a

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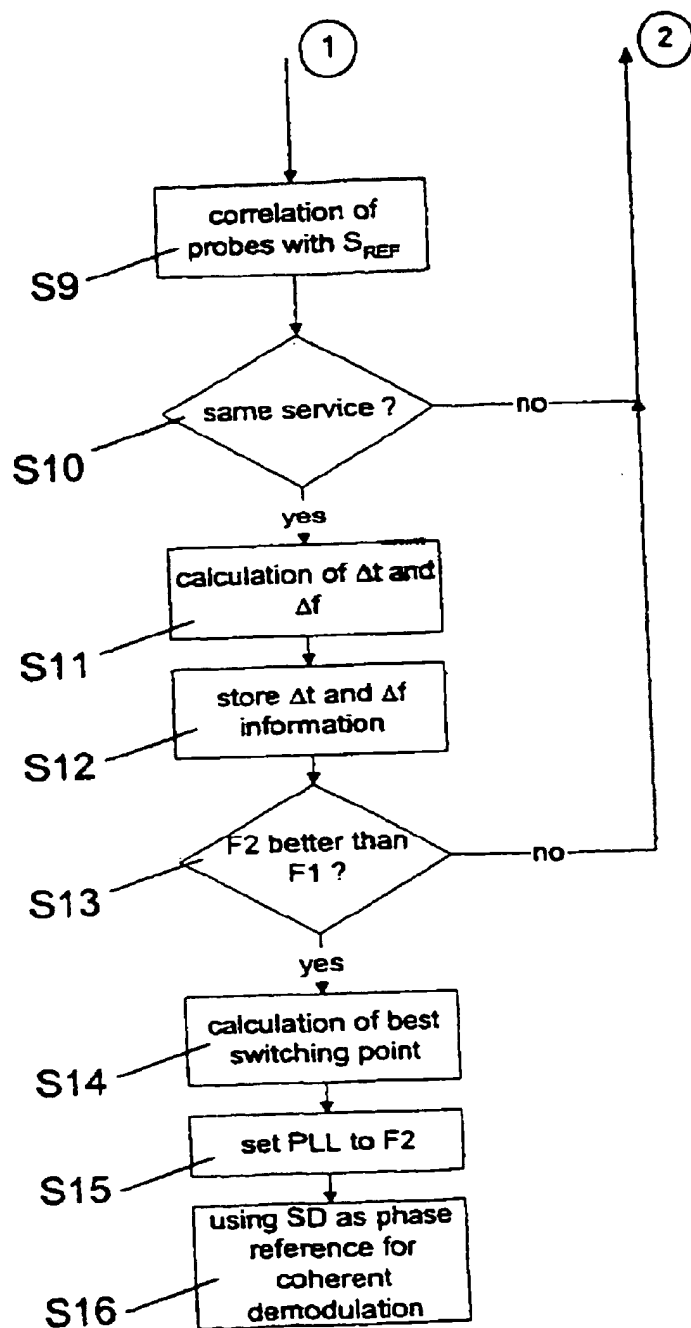


Fig. 8b

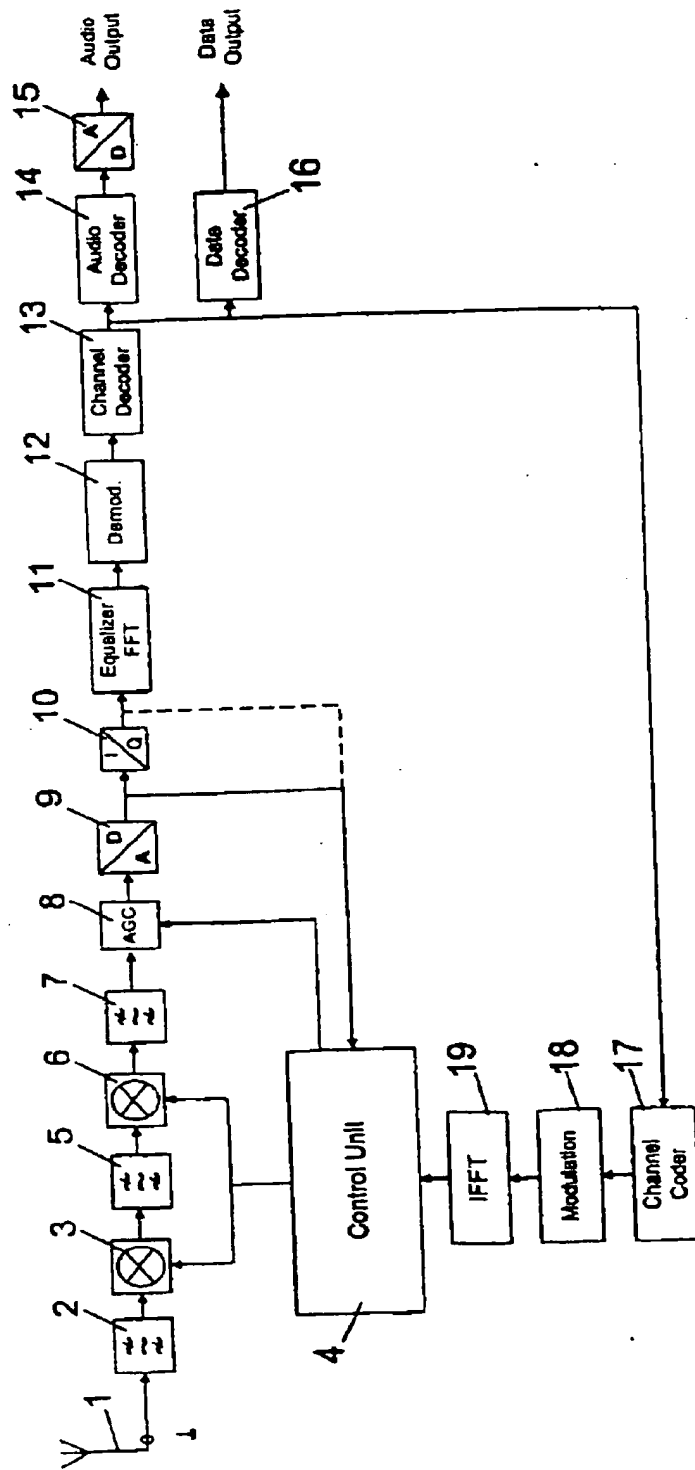


Fig. 9

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## EUROPEAN SEARCH REPORT

Application Number

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			H04H
The present search report has been drawn up for all claims			
Place of search <b>THE HAGUE</b>		Date of completion of the search <b>11 October 1999</b>	Examiner <b>Simon, V</b>
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons A : member of the same patent family, corresponding document			

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ANNEX TO THE EUROPEAN SEARCH REPORT  
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